

# **WFO Morristown, Tennessee Severe Weather Climatology**

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## **1. INTRODUCTION**

The purpose of the study is to provide forecasters with a greater understanding of the severe weather climatology of the County Warning Area (CWA) of Weather Forecast Office (WFO) Morristown, Tennessee (Fig. 1). This study is an update to the Hotz et al. (1998) National Weather Service Office (NWSO) *Morristown, Tennessee Severe Weather Climatology*. The frequency and magnitude of severe weather events along with seasonal, diurnal, topographical and demographic influences are highlighted. The National Weather Service (NWS) definition of severe weather includes one or more of the following: a tornado, convective wind gusts of 50 knots or greater, convective wind damage, and hail of three-quarters inch diameter or greater.

## **2. DATA**

Most of the data were obtained from the Storm Prediction Center's (SPC) tornado, hail, and wind damage database, which can be found under SPC's homepage (<http://www.spc.noaa.gov/>). The tornado database dates back to 1950 while the hail and wind database dates back to 1955. A local program was developed to quickly screen the databases to determine the severe weather climatology. Since the 2007 data was not included in SPC's database, the Storm Data publication from the National Climatic Data Center (NCDC) was used to fill in this year (NOAA 2007).

The SeverePlot Historical Severe Weather Report Analysis Program by John Hart, NCEP/SPC was used to plot tornado, hail, and convective wind gusts across the CWA.

## **3. TOPOGRAPHY**

The topography of the WFO Morristown, Tennessee CWA varies greatly from the Appalachian-Blue Ridge Mountains which lie on the eastern edge of Tennessee, bordering North Carolina, to the Great Tennessee valley (Fig 2). East Tennessee, southwest Virginia, and southwest North Carolina are characterized by high mountains, including the Great Smoky Mountains with average elevations around 5,000 feet above sea level.

To the west of the Appalachian Mountains is the Great Valley of East Tennessee which extends from southwestern Virginia into northern Georgia. The Cumberland Plateau lies just west of the Great Tennessee Valley and extends from southern Kentucky into central Alabama.

The topography of the CWA has a major impact on thunderstorm development and corresponding severe weather climatology. Under weak forcing, upslope flow pushes low-level

moisture across the higher terrain resulting in orographically induced pulse storms that can result in severe weather. These storms and associated outflow boundaries often move into the Great Tennessee Valley in the summer months during the late afternoon and evening hours.

The mountainous terrain also plays a role of limiting moisture return into the CWA. Cold air damming east and south of the CWA is common during the winter and spring which limits the low level moisture and instability return into the region. Convection that develops west of the WFO Morristown, Tennessee CWA often weakens as it approaches the cooler and stable airmass, which tends to decrease the number of severe weather events.

#### **4. DEMOGRAPHICS**

WFO Morristown, Tennessee assumed full warning responsibilities from the Weather Service Offices (WSO) in Chattanooga, Knoxville, and Tri-Cities by the early summer of 1995. WFO Morristown has warning responsibilities for 40 counties, including 33 counties in east Tennessee, 5 counties in southwest Virginia, and 2 counties in extreme southwest North Carolina. The Morristown CWA comprises 15,982 square miles with a population of 2,369,422 (U.S. Census Bureau 2004). A number of tornado climatology studies have pointed out that one of the major limitations in producing severe weather climatology is a bias from population density. To provide a better sense of the population across the CWA, a county map of average population per square mile has been provided (Fig 3). The main population centers of the CWA are Knoxville, Chattanooga, and Tri-Cities; the 3<sup>rd</sup>, 4<sup>th</sup>, and 5<sup>th</sup> most populated metropolitan areas in Tennessee, respectively.

Many sections of the CWA are comprised of heavily forested or rural farmland, and therefore are sparsely populated. Several of the counties have a low population density, especially those encompassing the higher elevations, such as the Appalachian Mountains and Cumberland Plateau. This uneven distribution of people across the CWA can lead to skewing of the severe weather reports toward the more heavily populated areas.

#### **5. TORNADO CLIMATOLOGY**

Tornadoes have been reported in almost every county, except for Campbell and Sevier counties of Tennessee (Fig. 4). The counties of Bradley, McMinn, and Knox reported the greatest number of tornado events. Since 1950, a total of 167 tornadoes have been reported across the CWA with the maximum of 30 events in 1974 (Fig. 5). The map of plotted tornado paths from 1950 to 2007 (Fig. 6) shows the majority of the events occurred across the Plateau and southern half of the Great Tennessee Valley.

The months of March through May account for 63 percent of the total yearly tornadoes with April being the peak month (Fig. 7). It is interesting that only 1 tornado has been reported during the month of September since 1950. A weak secondary maximum of tornadoes is noted in November. A recent notable tornado outbreak is the deadly Mossy Grove and Petros tornadoes of November 10<sup>th</sup>, 2002.

The hourly distribution of tornadoes reveals that 57 percent occurred between 2 and 9 pm EST (Fig. 8), which corresponds to the peak heating of the day. The greatest hourly occurrence is between 5 and 6 pm EST with 22 tornado reports. No tornadoes were reported between 5 and 6 am EST. A majority of the tornadoes or 77 percent had lengths of less than 10 miles (Fig. 9).

A majority or 62 percent were reported as weak (F0-F1) tornadoes (Fig. 10) on the Fujita Scale (Fujita 1981). The Fujita scale (Table 1) was developed in the 1960s to rate the intensity of a tornado by examining the damage caused by the tornadic winds. The NWS changed the method of rating tornadoes to the Enhanced Fujita (EF) scale in 2007.

A Study by Ostby (1993) suggested that a more important and reliable climatology study may be found by focusing on the most severe events, such as those with F2 tornado intensities or higher. Ostby stated “significant” tornadoes or those classified on the Fujita scale as F2-F5 (Fujita 1973), cause much of the damage and most of the deaths each year. A total of 64 F2 tornadoes have been reported during the past 55 years with a large percentage occurring during the super outbreak of 1974 (Fig. 11). A majority of the strong tornadoes (25) occurred during the month of April making up almost half of the monthly total (Fig. 12). For the months from January through April, 50 of the total 94 tornadoes were rated as F2 or greater. This was likely due to the continued presence of differential temperature boundaries and sufficient low-level shear, combined with increasing low level instability during the spring months.

The majority of the tornadoes rated F2 or greater occurred across the southern sections of the Great Tennessee Valley with both Bradley and McMinn counties having 8 each (Fig. 13). The only F4 tornadoes across the CWA occurred across McMinn and Meigs counties of Tennessee in May 2, 1953, and Cherokee County, North Carolina in April 3, 1974.

## **6. CONVECTIVE DAMAGING WINDS CLIMATOLOGY**

Convective damaging winds are quite common across the CWA, with reports observed every year since 1955 (Fig. 14). A dramatic increase in events occurs after 1994, which corresponds to the opening of WFO at Morristown, Tennessee. We will propose several reasons for the large increase in number of convective damaging wind events in the severe weather trends sections. Over the last 50 years, damaging winds have been reported in every county across the CWA with Hamilton, Knox, and Blount counties with the greatest number of reports (Fig. 15).

There have been 4280 reports of convective wind damage across the WFO Morristown, Tennessee CWA since 1955, making this type of severe weather phenomenon the most common.

The majorities, or 63 percent of damaging wind events, were reported during the three-month period of May through July (Fig. 16). July is the peak month for damaging winds with 26 percent, and May a close second with 25 percent of the events reported. The peak month for damaging winds is later than for large hail. Physical reasons for the mid-summer maximum may include that precipitable water values and tropopause heights are near their highest for the year, allowing deep, moist convection, capable of producing wet microbursts. Johns and Doswell (1992) note that deep convection and large precipitable water amounts help to enhance damaging winds by promoting strong downdrafts. The occurrence of convective damaging winds

decreases dramatically during the Fall and Winter months (September through March) with only 16 percent of the events.

The hourly distribution of damaging winds shows that the majority of the events occurred between 2 and 8 pm EST (Fig. 17). The peak hours of 4 to 6 pm EST accounted for 24 percent of the events. The mid-afternoon to early evening maxima in damaging wind reports indicate the important role surface heating plays in increasing the CAPE necessary for pulse-type severe thunderstorms. The number of reports decreased sharply during the late evening and early morning hours with only 13 percent of the events between 1 am and noon EST.

The majority of the convective damaging wind events were associated with reports of 50 knot winds or reports where significant damage occurred, yet wind speeds were not reported. These events are depicted in the graph with events equal to 50 knots, which accounted for 59 percent of the events (Fig. 18). Damaging winds of 56 to 60 knots accounted for 25 percent of the total events. The strongest estimated wind reported was 100 knots near Clinton in Anderson county, Tennessee at 545 pm EST on May 5<sup>th</sup>, 1999.

## **7. LARGE HAIL CLIMATOLOGY**

The plot of large hail across the CWA between 1955 and 2006 shows reports in every county (Fig. 19). Hamilton, Knox, and Bradley counties in southeast Tennessee reported the most events while counties in far northeast Tennessee and southwest Virginia reported the least. Large hail, defined as greater or equal to 0.75 inch in diameter, is a common occurrence across the CWA, with reports observed every year since 1955 (Fig. 20).

Since 1955, there have been 1429 events of large hail across the WFO Morristown, Tennessee CWA with 68 percent of the reports occurring from April through June (Fig. 21). May is the peak month for large hail with 26 percent, and April a close second with 23 percent of the events reported. The reason for the peak occurrence of hail during the months of May and April is due the greater frequency of supercells. The presence of vertical shear and increasing CAPE during the spring months combine to produce stronger longer lasting updrafts. Large hail can occur with non-supercells but require an environment with at least moderate CAPE and relatively low Wet Bulb Zero (WBZ) heights. The occurrence of large hail decreases dramatically during the Fall and Winter months (September through February) with only 12 percent of the events.

The hourly distribution of large hail shows that the majority of the events occurred between 2 and 9 pm EST (Fig. 22). The peak hours of 4 to 6 pm EST accounted for 26 percent of the events. The number of reports decreased sharply during the late evening and early morning hours with only 13 percent of the events between Midnight and noon EST. Large hail is uncommon between 4 and 8 am EST with a total 10 or less events reported per hour since 1955.

One inch or less diameter hailstones represented the majority, or 77 percent, of the large hail events (Fig. 23). Hail size reports between 1.5 and 2 inches accounted for 15 percent (218) of the total events. The largest hail reported was 4.25 inches near Tazewell in Campbell County, Tennessee at 215 pm CST on June 6<sup>th</sup>, 2007.

## **8. SEVERE WEATHER TRENDS**

The total number of severe weather reports across WFO Morristown, Tennessee CWA increased sharply during the 55+ year study period. The period between 1995 and 2007 accounted for 81 percent of the total convective damaging wind events (3487 of 4280), 80 percent of the large hail (1136 of 1429), and 29 percent of the tornadoes (49 of 167).

This impressive trend can be attributed to numerous causes: improved technology for severe weather detection, more aggressive verification procedures, improved spotter networks, an increase in public awareness and knowledge of severe weather, and an increase in the population and urbanization. Interestingly, while the total number of recorded severe weather events has increased dramatically during the past 17 years, the total number of tornadic events has not.

## **9. CONCLUSION**

The updated severe weather climatology for the WFO Morristown, Tennessee CWA gives forecasters a better understanding of the frequency and distribution of tornadoes, hail, and convective damaging winds. The data from the previous study (Hotz-Labounty 1998) ended in 1995, so the results did not capture the dramatic change in the severe weather climatology during the past 13 years.

As would be expected, the peak time for all types of severe weather occurs from mid-afternoon to early evening. The maps showing the number of events per county were useful in determining areas which are more susceptible to severe weather. The CWA maps showed that a majority of the tornadoes occur across southern sections of the Great Tennessee Valley. The tornado maximum across southeast Tennessee may be attributed to its closer proximity to the moisture originating from the Gulf of Mexico, and are typically less affected by stable cold air damming in the Great Tennessee Valley.

The low level wind profile is likely more favorable for significant tornadoes across the southern valley than the central and northern Tennessee valley due to the southwest-northeast orientation of the Great Tennessee Valley. The wind roses (Fig. 24) from February through July show a more southwesterly low level flow at the Knoxville airport versus the Chattanooga airport. The more southwesterly flow across the central and northern sections of the Great Tennessee Valley likely produces a less favorable vertical wind profile for sustained updrafts and tornadogenesis. Additional research of the effects on the orientation of the Great Tennessee Valley on tornadogenesis is needed.

## **10. ACKNOWLEDGEMENTS**

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## TABLES AND FIGURES

Table 1. Fujita and Enhanced Fujita Scales. Fujita (1981)

<b>Fujita Scale</b>	<b>Wind Speed (mph)</b>	<b>Damage Description</b>	<b>Enhanced Fujita Scale</b>	<b>Wind Speed (mph)</b>
<b>F0</b>	40-72	Light	EF0	65-85
<b>F1</b>	73-112	Moderate	EF1	86-110
<b>F2</b>	113-157	Significant	EF2	111-135
<b>F3</b>	158-207	Severe	EF3	136-165
<b>F4</b>	208-260	Devastating	EF4	166-200
<b>F5</b>	261-318	Incredible	EF5	Over 200



Figure 1. WFO Morristown, Tennessee County Warning Area (CWA).



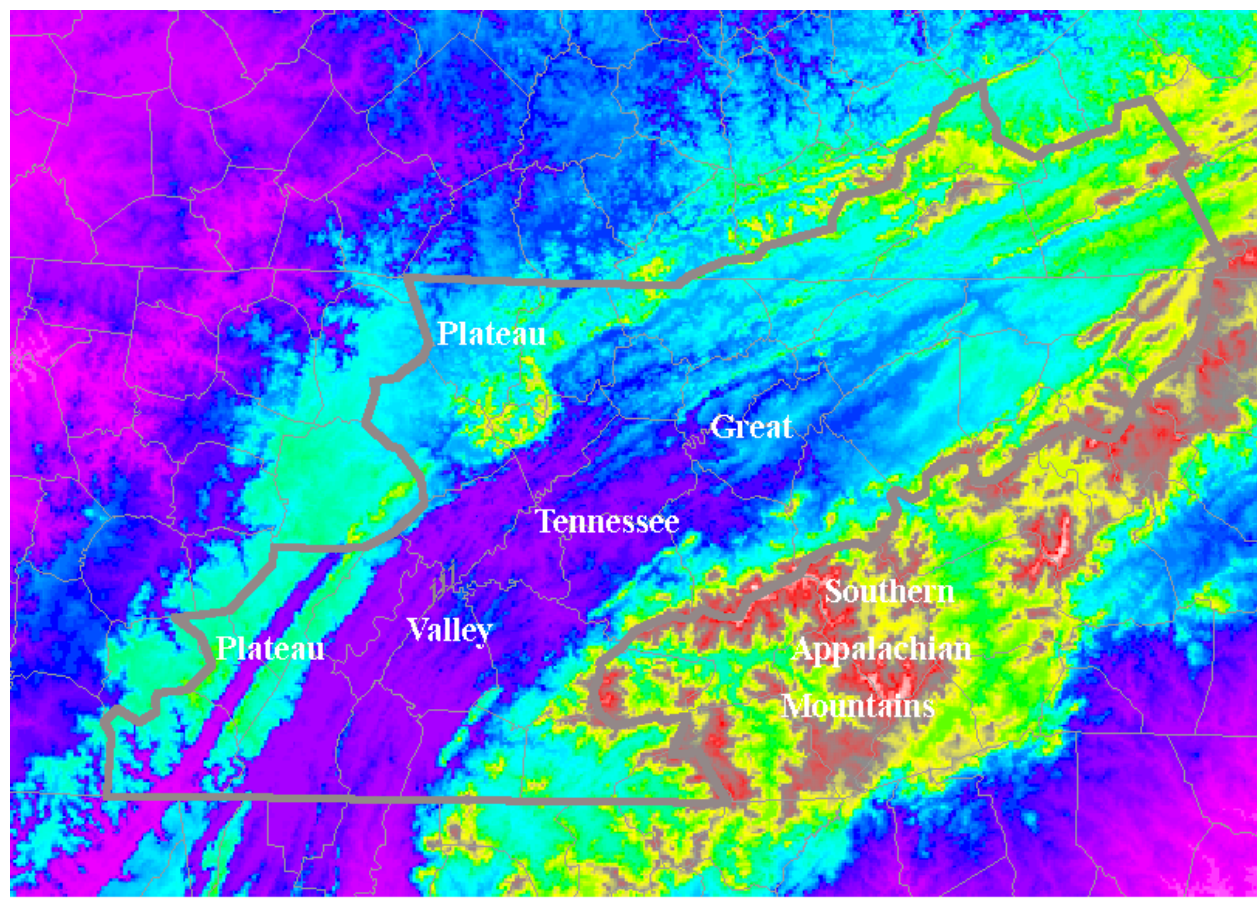


Figure 2. Topography of WFO Morristown, Tennessee CWA.

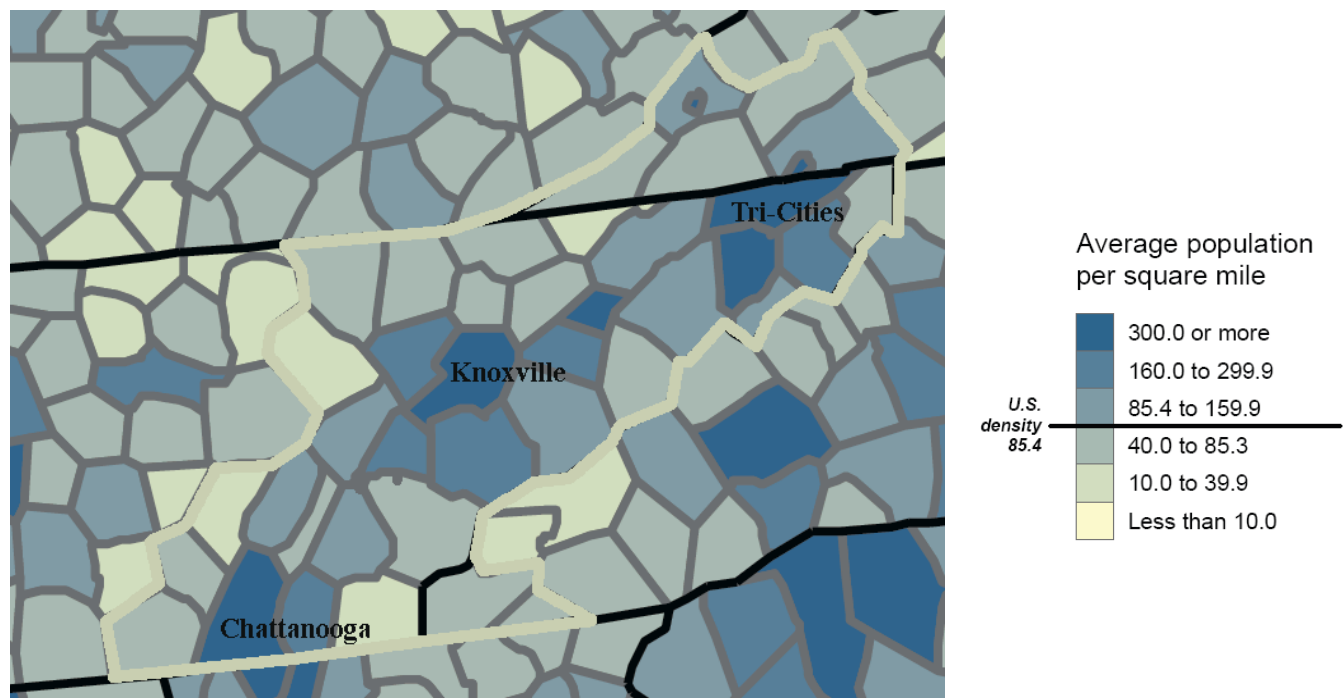


Figure 3. Average population per square mile of WFO Morristown, Tennessee CWA.



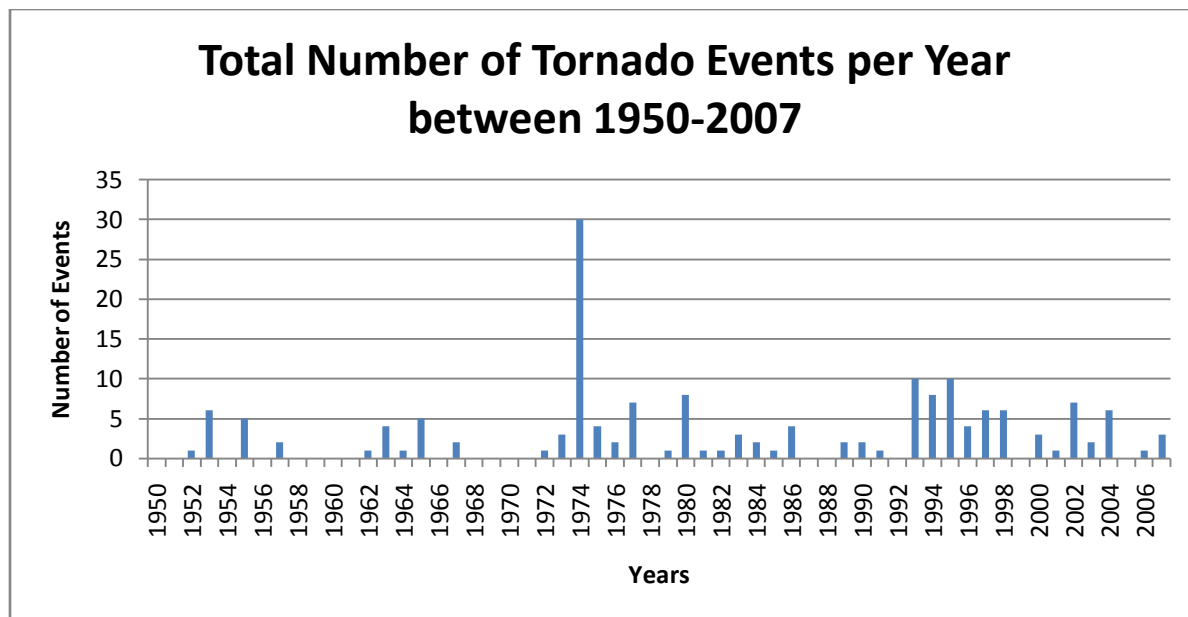


Figure 5. Number of Tornadoes per Year between 1950 and 2007.

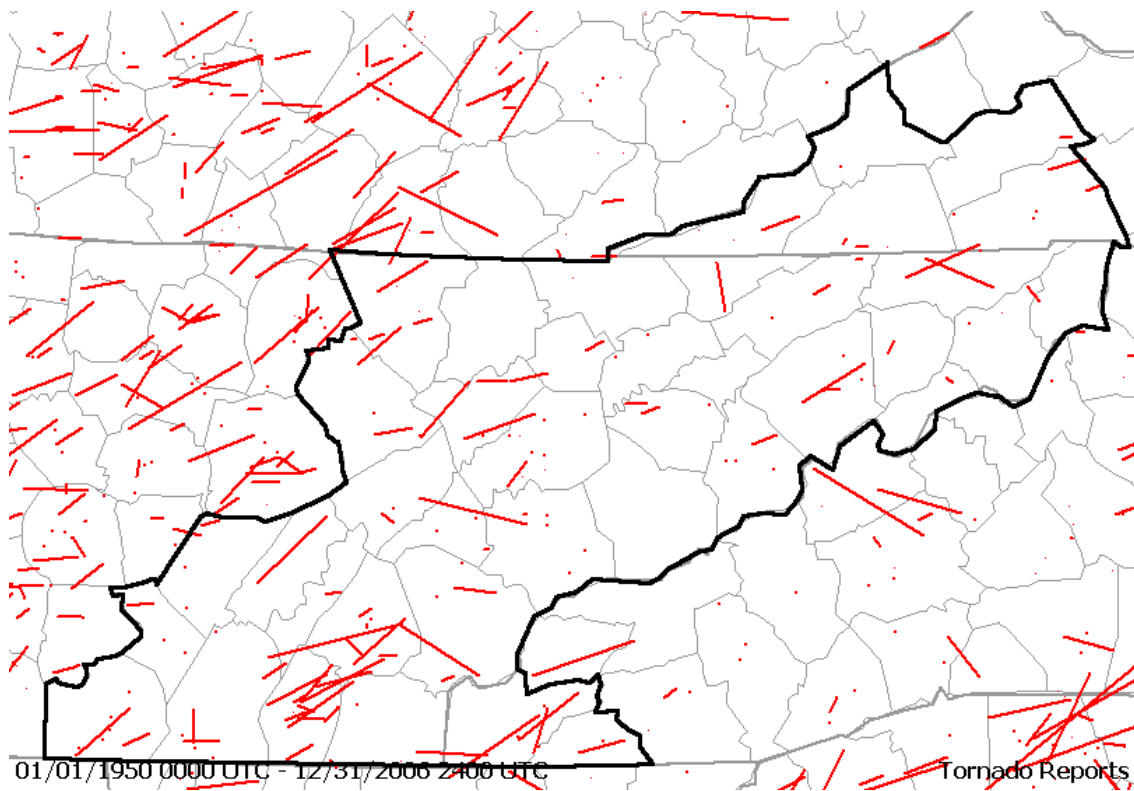


Figure 6. Tornado tracks between 1950 and 2006. Note: Data for 2007 was not available for plotting at the time of this publication.

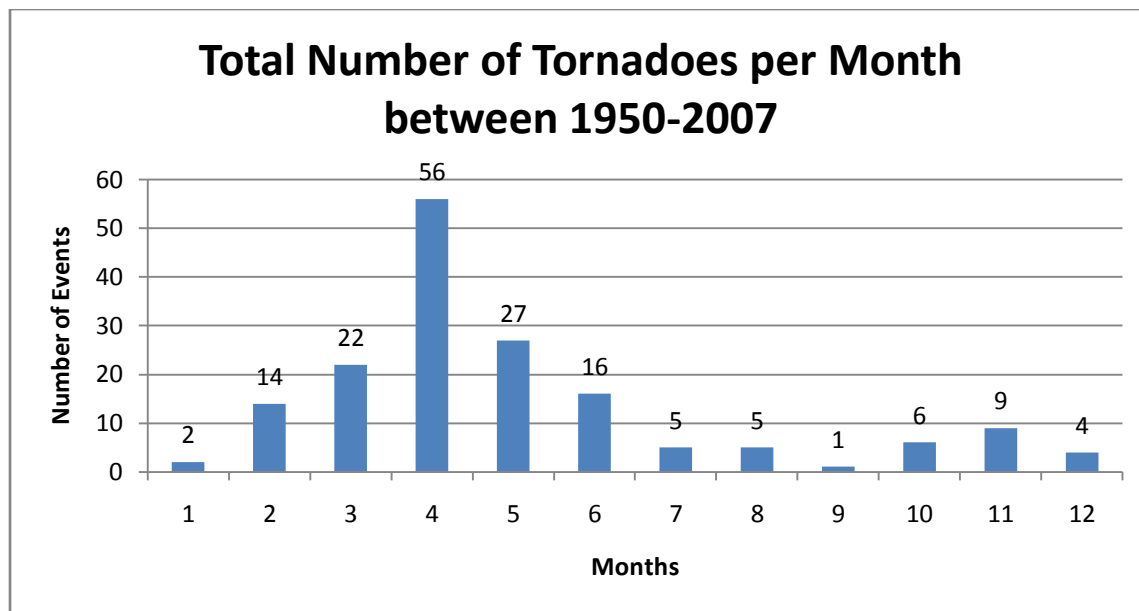


Figure 7. Number of tornadoes per month between 1950 and 2007.

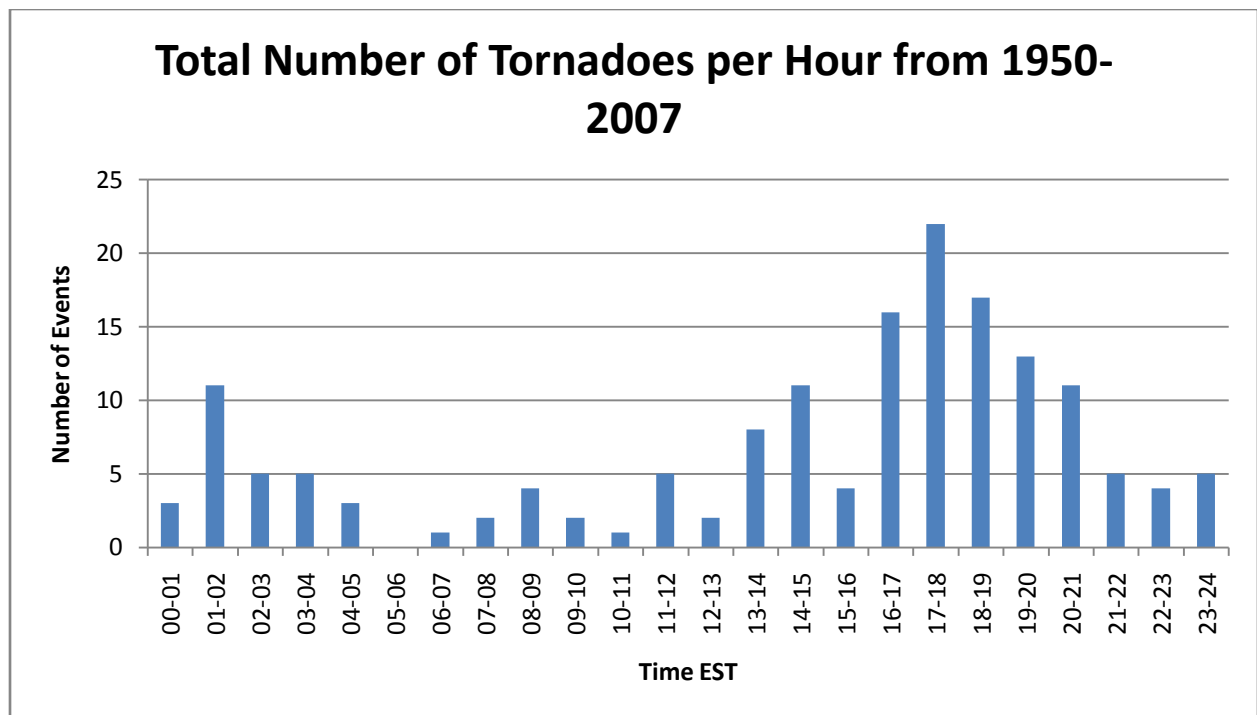


Figure 8. Number of tornadoes per hour between 1950 and 2007.

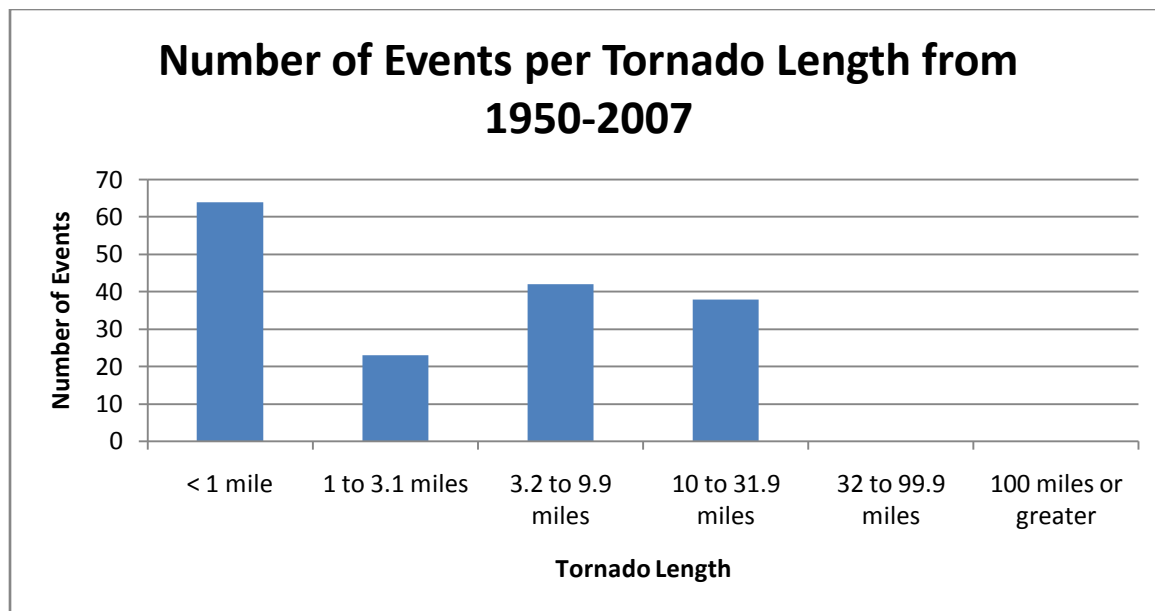


Figure 9. Number of events per tornado length between 1950 and 2007.



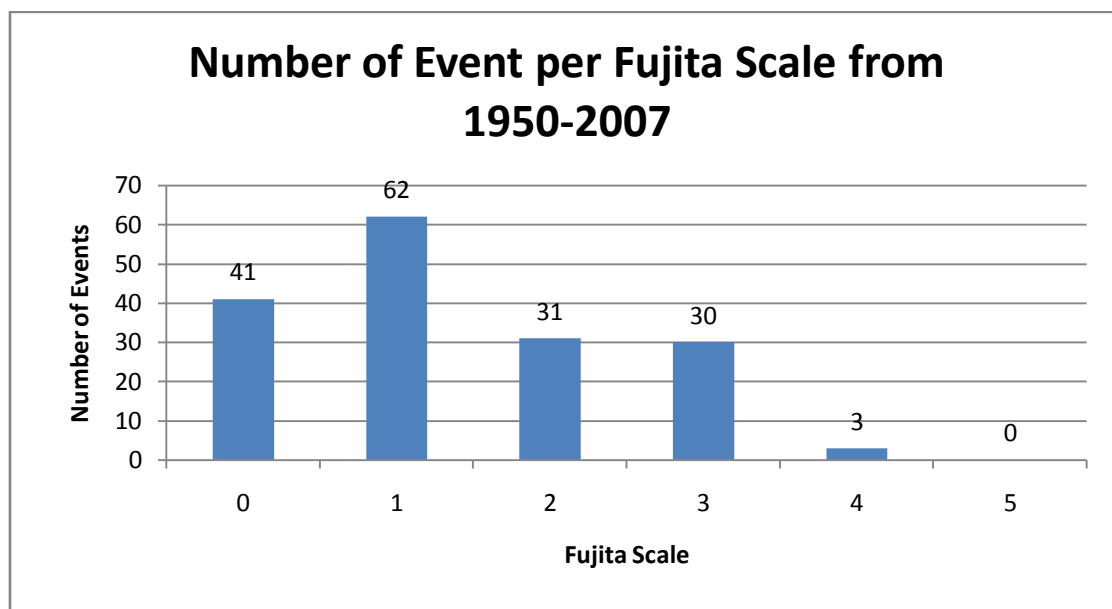


Figure 10. Number of events per fujita scale between 1950 and 2007.

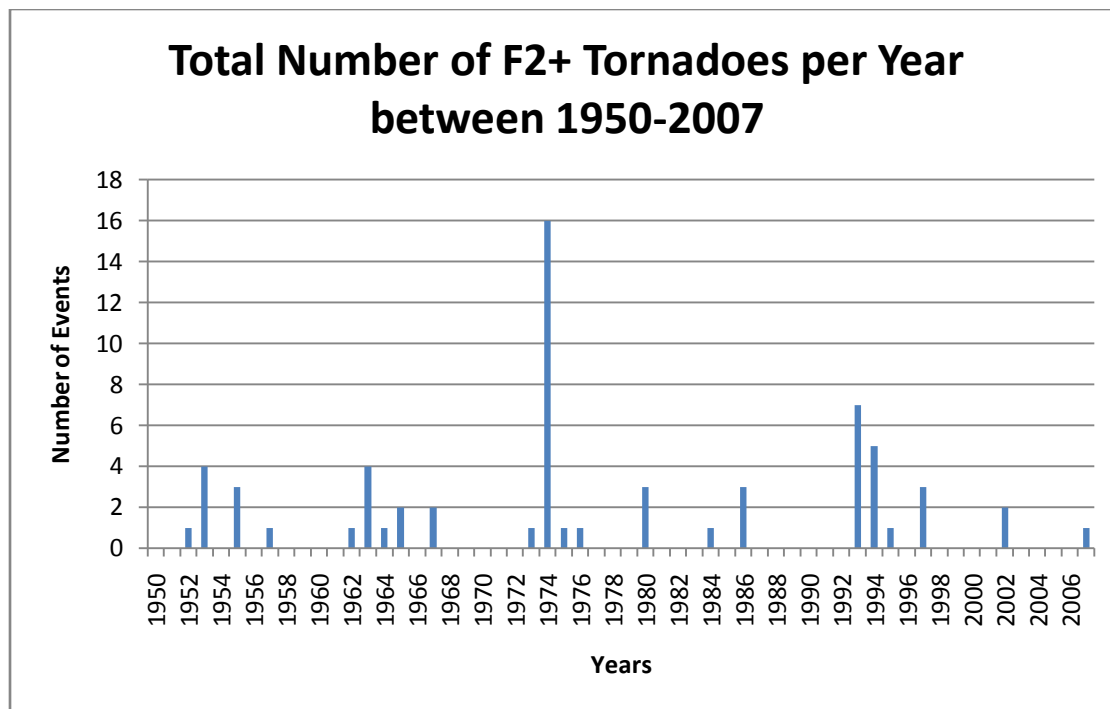


Figure 11. Number of F2 intensity or greater tornadoes per year between 1950 and 2007.

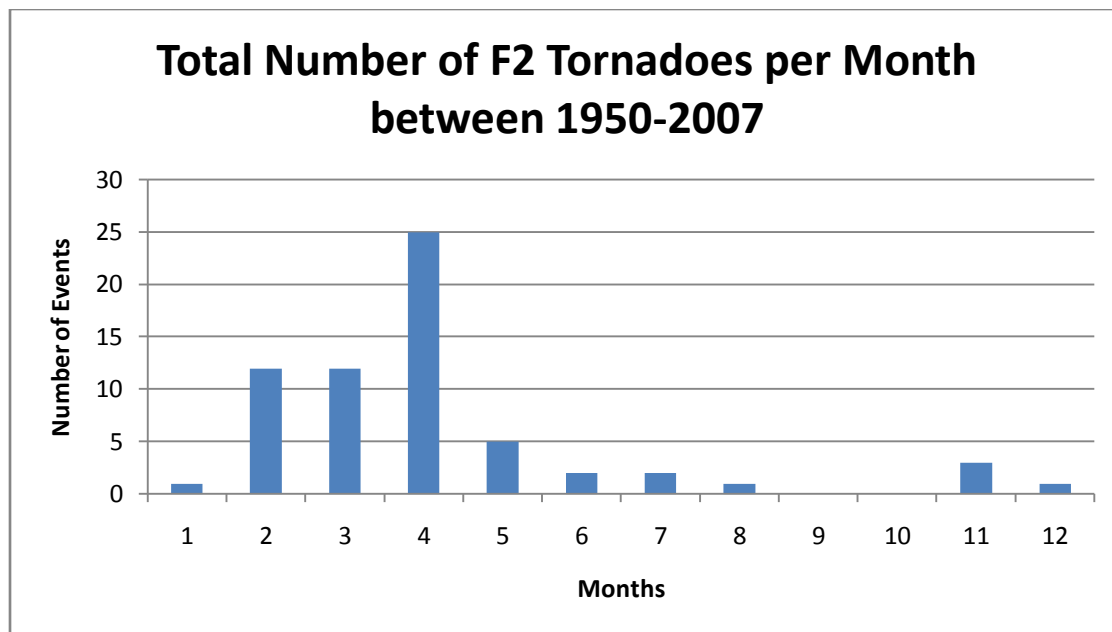


Figure 12. Number of F2 intensity or greater tornadoes per month between 1950 and 2007.

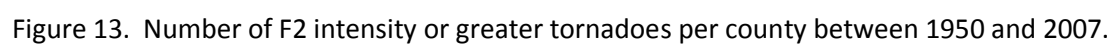


Figure 13. Number of F2 intensity or greater tornadoes per county between 1950 and 2007.

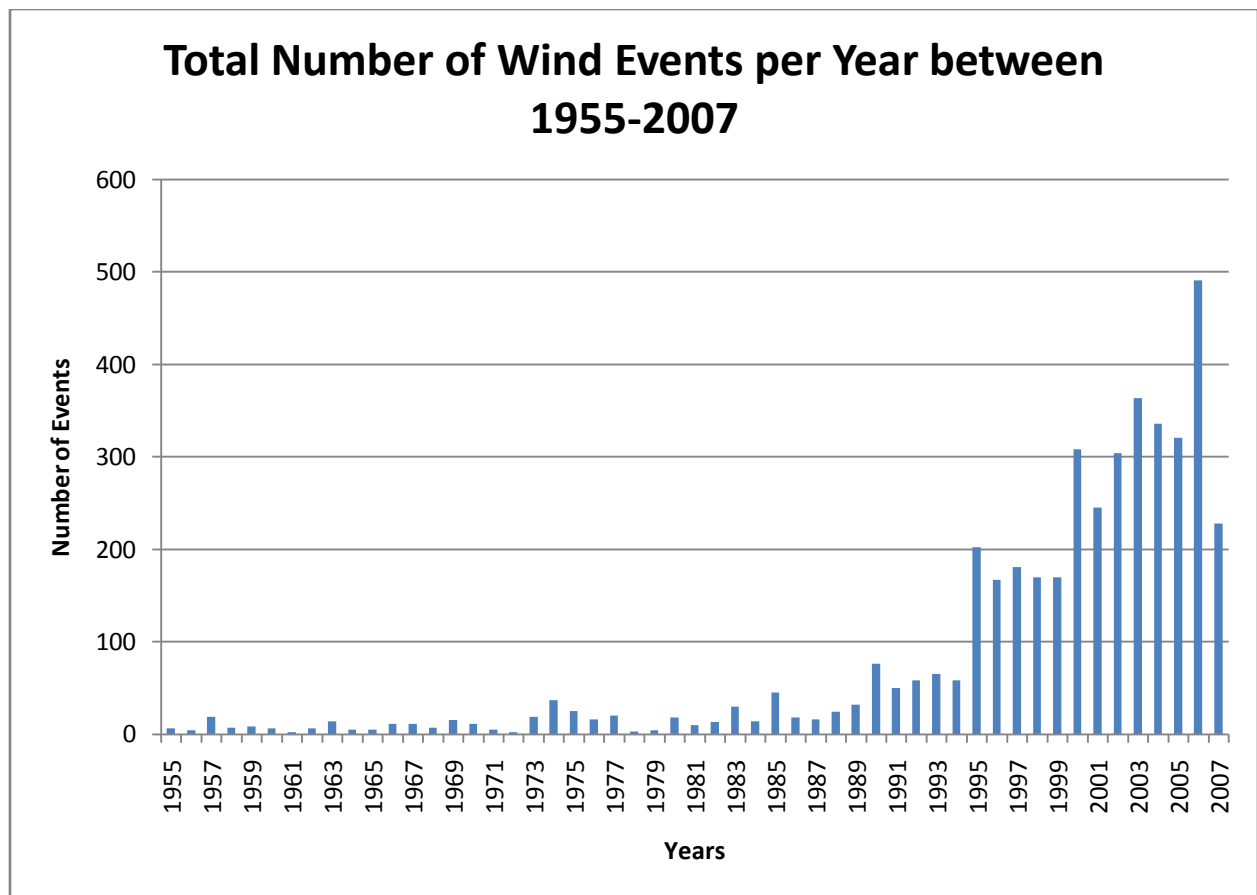


Figure 14. Number of wind events per year between 1955 and 2007.



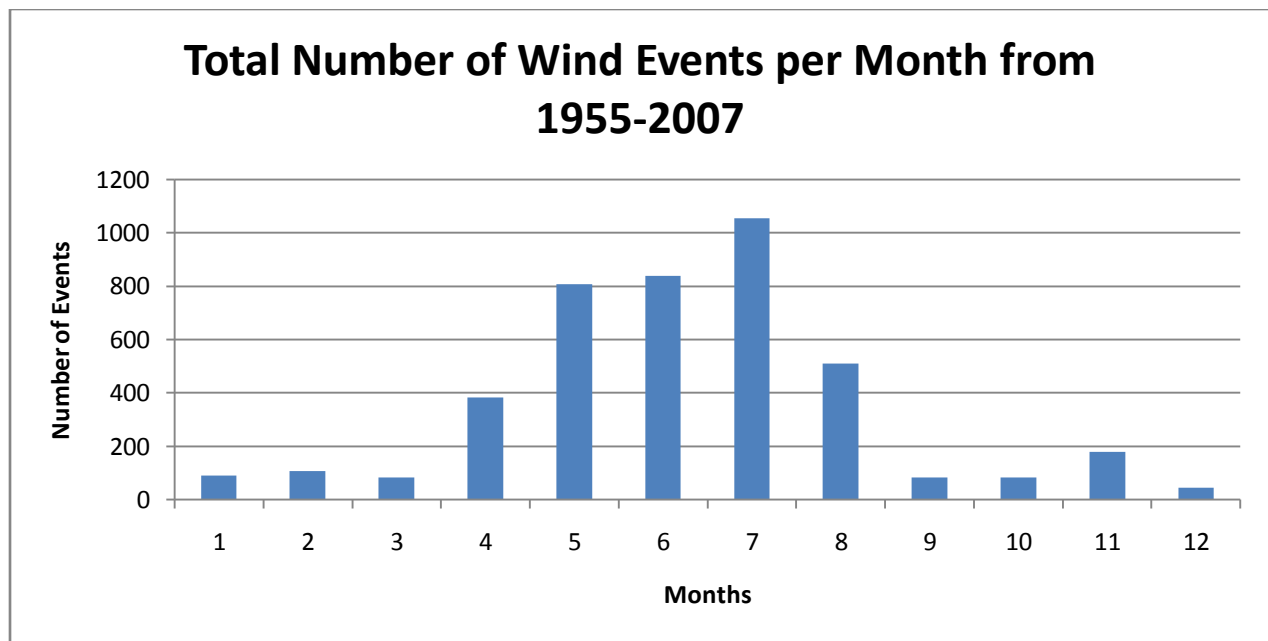


Figure 16. Number of wind events per month between 1955 and 2007.

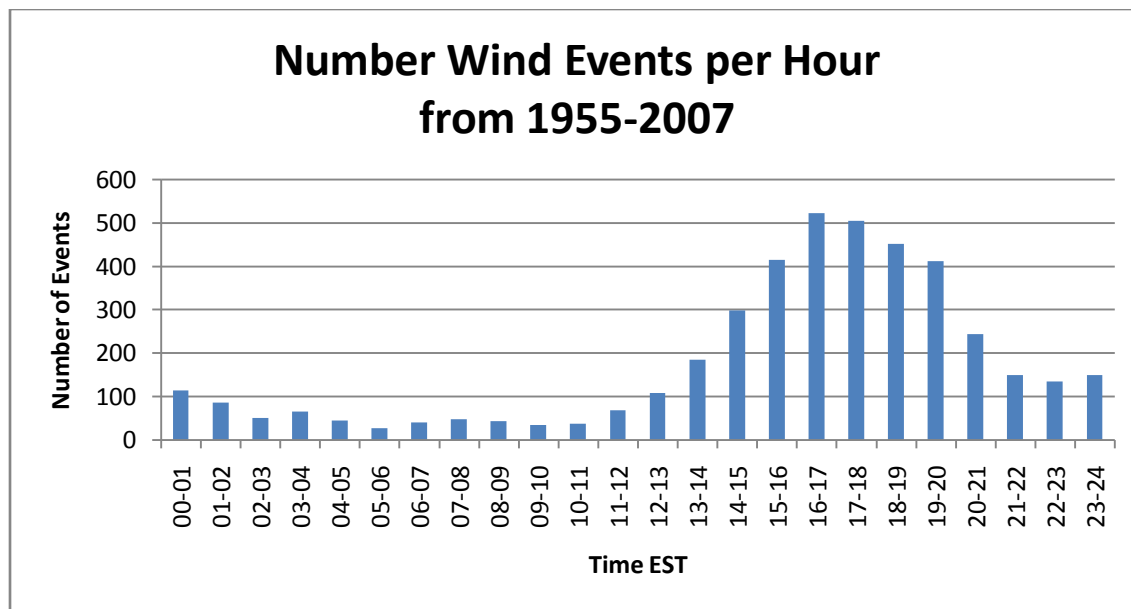


Figure 17. Number of damaging wind events per hour between 1955 and 2007.



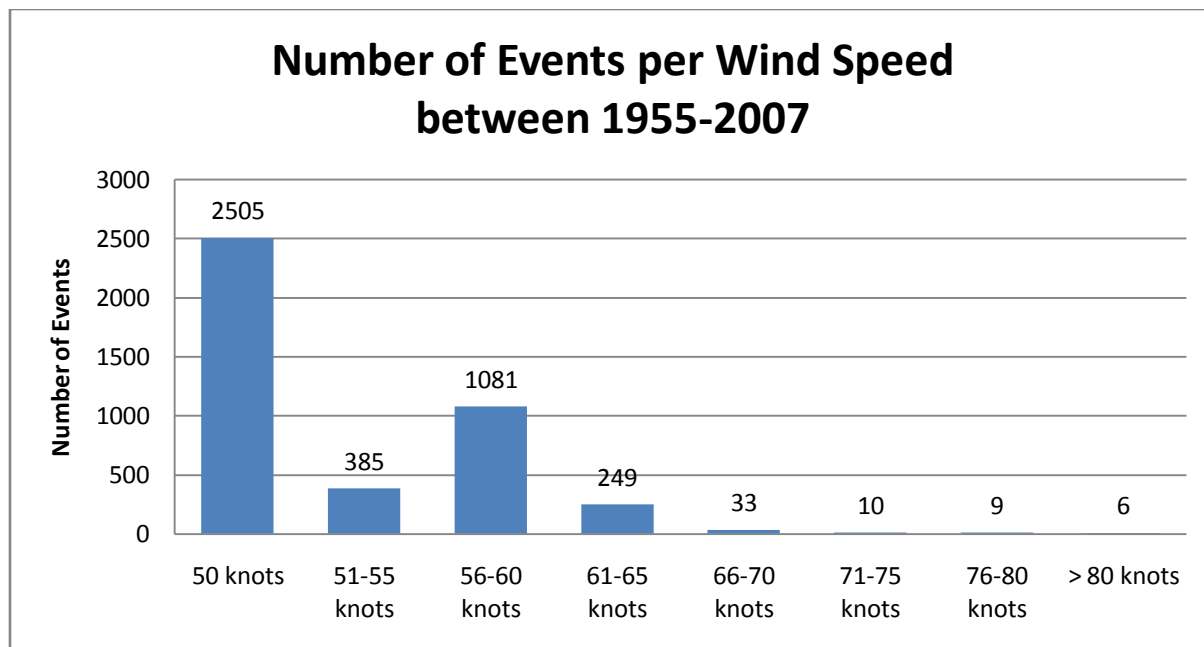


Figure 18. Number of damaging wind events per wind speed between 1955 and 2007.

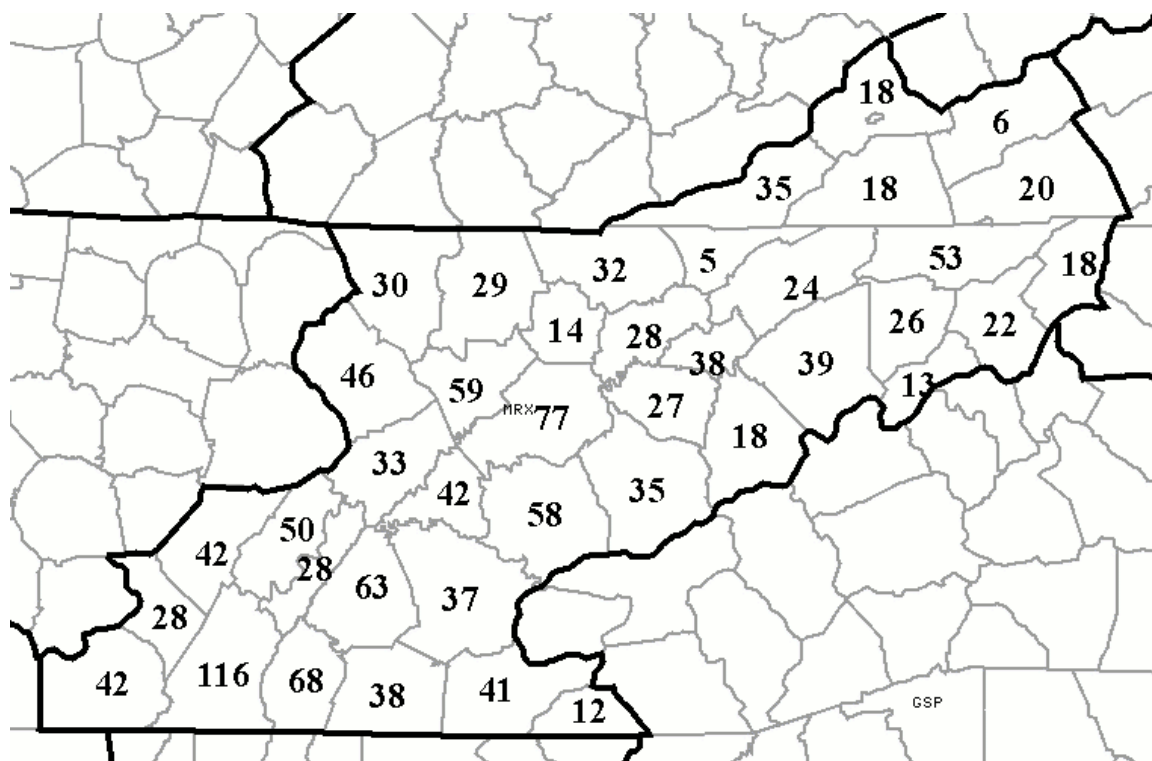


Figure 19. Number of large hail events per county between 1955 and 2007.

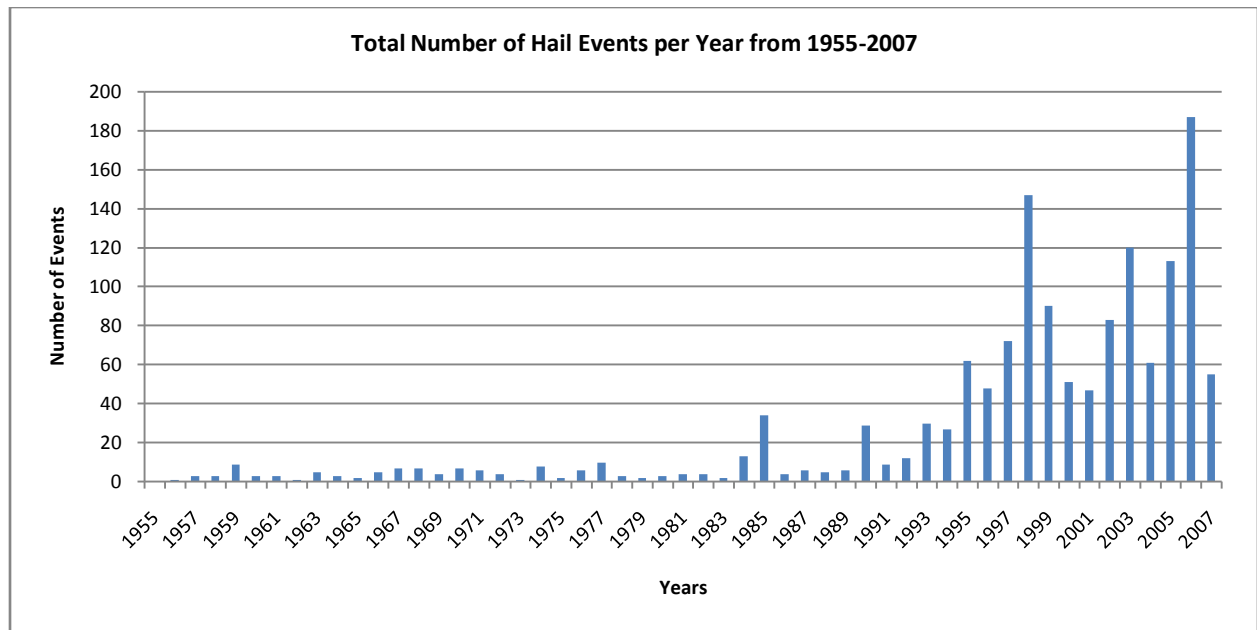


Figure 20. Number of large hail events per year between 1955 and 2007.

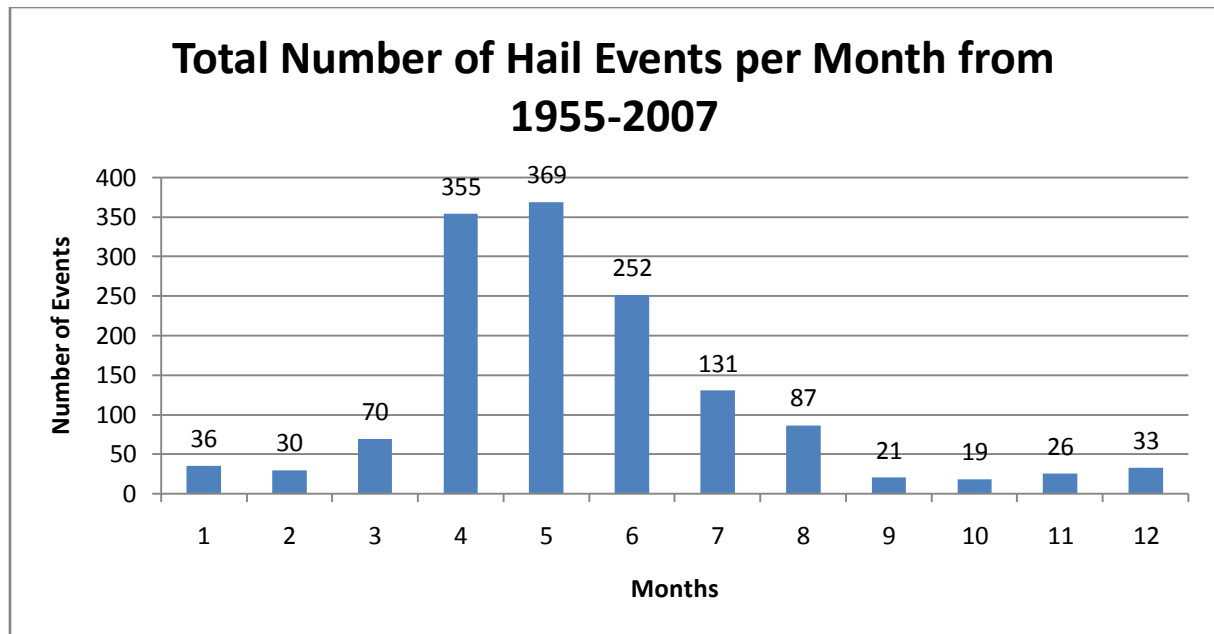


Figure 21. Number of large hail events per month between 1955 and 2007.

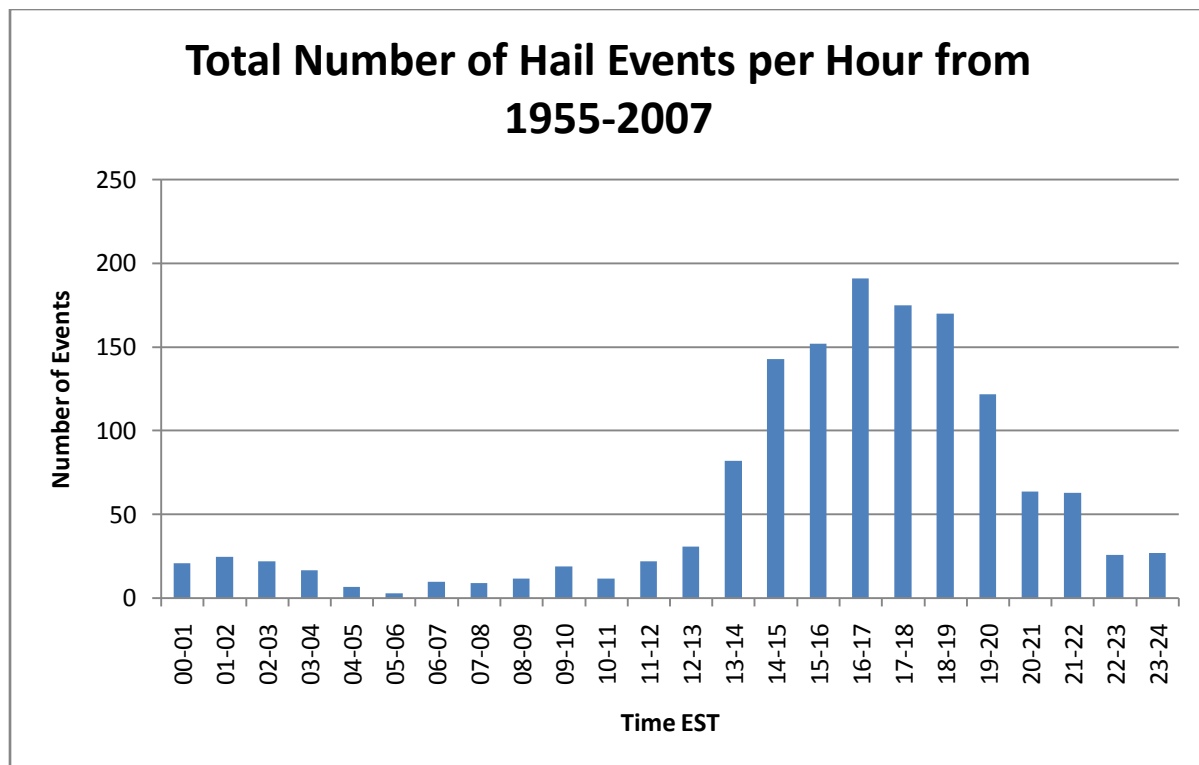


Figure 22. Number of large hail events per hour between 1955 and 2007.

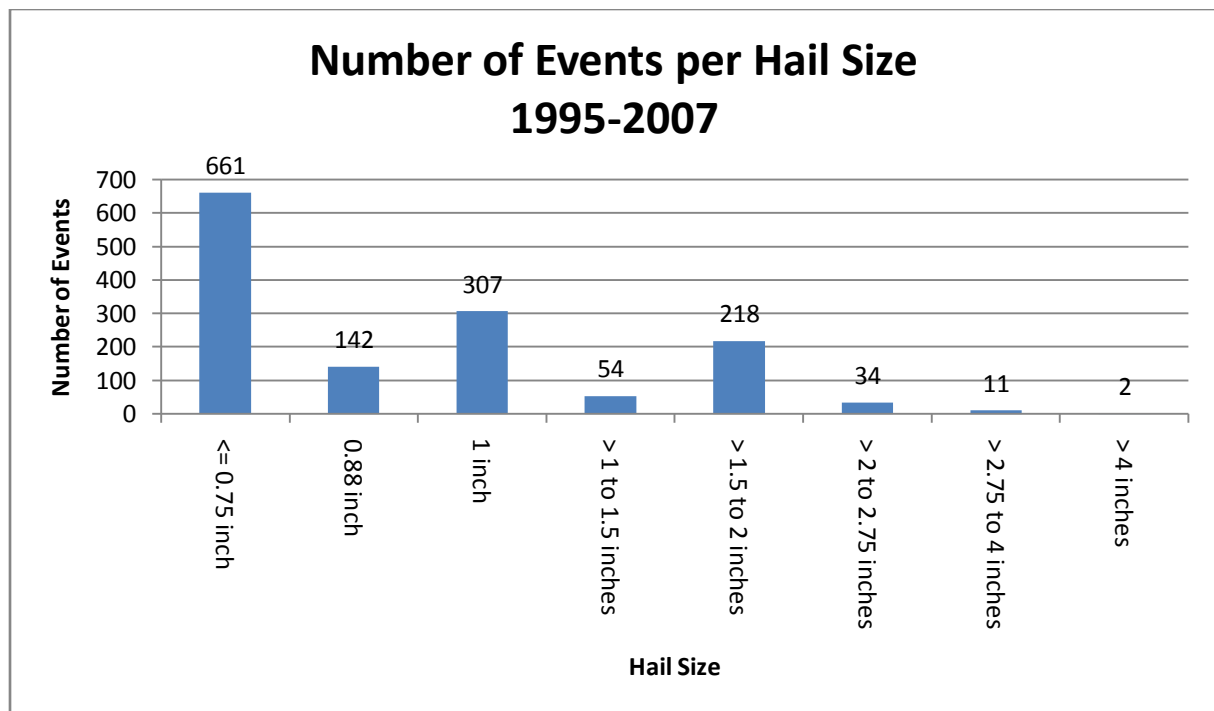


Figure 23. Number of events per hail size between 1955 and 2007.

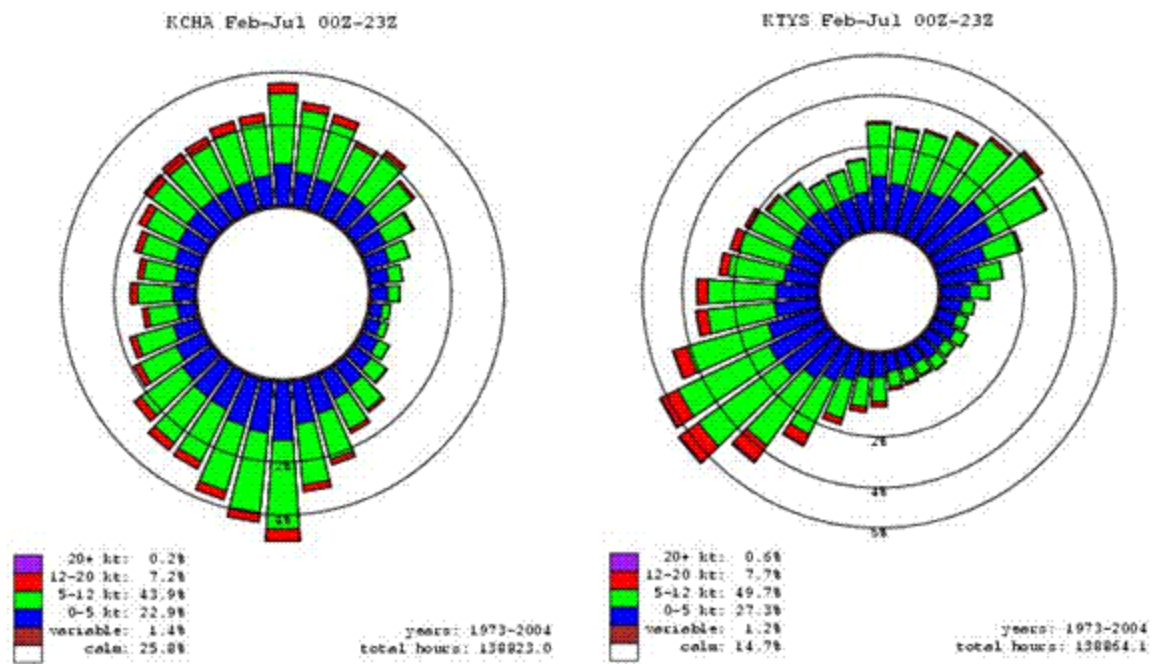


Figure 24. Wind Rose for Chattanooga and Knoxville airports for February through July.